US Army Corps of Engineers

How to Take a Truly Representative Environmental Sample

John P. Jent, P.E.

INTRODUCTION

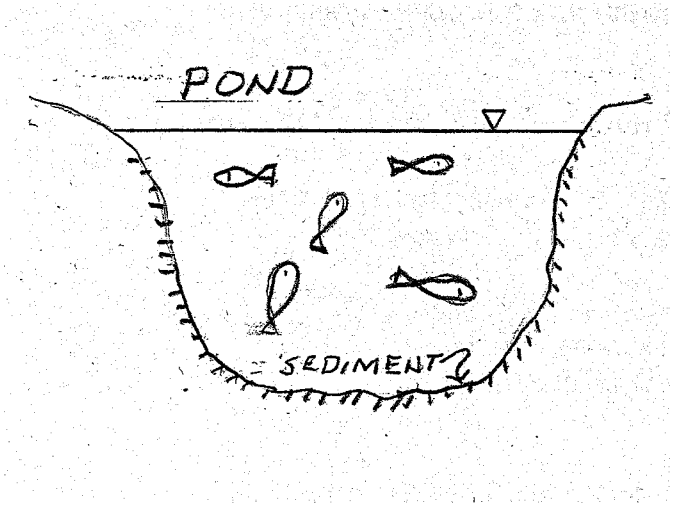
1 Discuss things we usually don't talk about, even though they have huge significance, such things as,

- how to take a representative sample
- how to prepare a representative sub-sample in the field for shipment to the lab
- how the lab should select a representative 1 or 2 gm sub-sample from the jar shipped from the field to the lab

2 Even though the things we discuss result in huge problems for us, and huge deficiencies in our current methods of operation, the solutions are so common sense that you can't refute them

3 Hope you leave wondering why in the world we haven't tackled these issues before now. I

ECOLOGICAL



- **Ecological - Ravenna streams and ponds flunk screening criteria for surface water and sediment**
- **Flunk Screening Criteria ------Field Verification (fish and macro-invertebrate populations)**

ECOLOGICAL

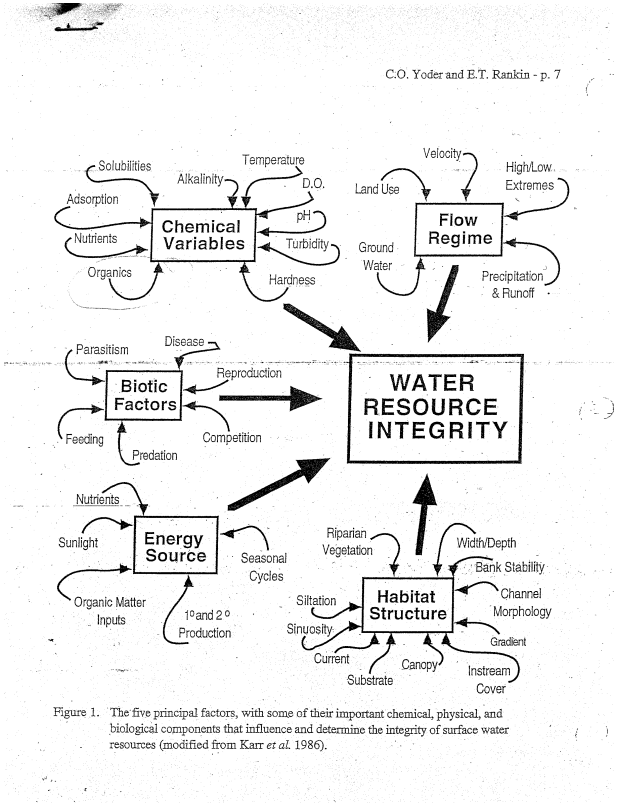


Figure 1. The five principal factors, with some of their important chemical, physical, and biological components that influence and determine the integrity of surface water resources (modified from Karr *et al.* 1986).

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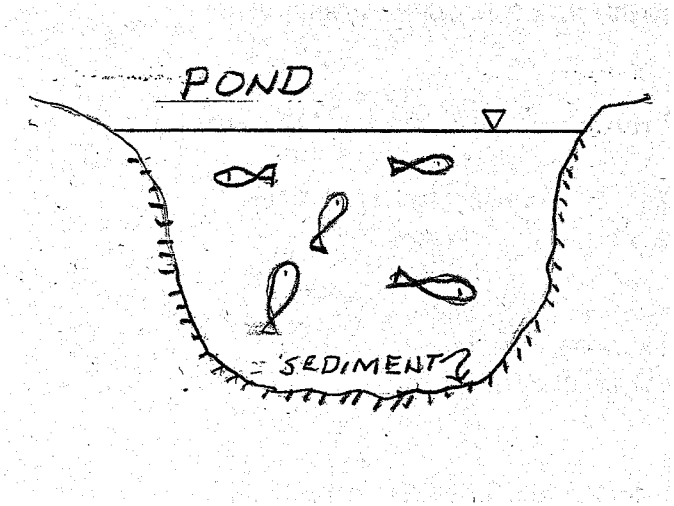

- **Ecological - Ravenna streams and ponds flunk screening criteria for surface water and sediment; concern for ecological concern**
- **Flunk Screening Criteria ------Field Verification (fish and macro-invertebrate populations)**
  - **Index of Biotic Integrity (IBI) - health of fish**
  - **Invertebrate Community Index (ICI)- health of bugs**
  - **Qualitative Habitat**

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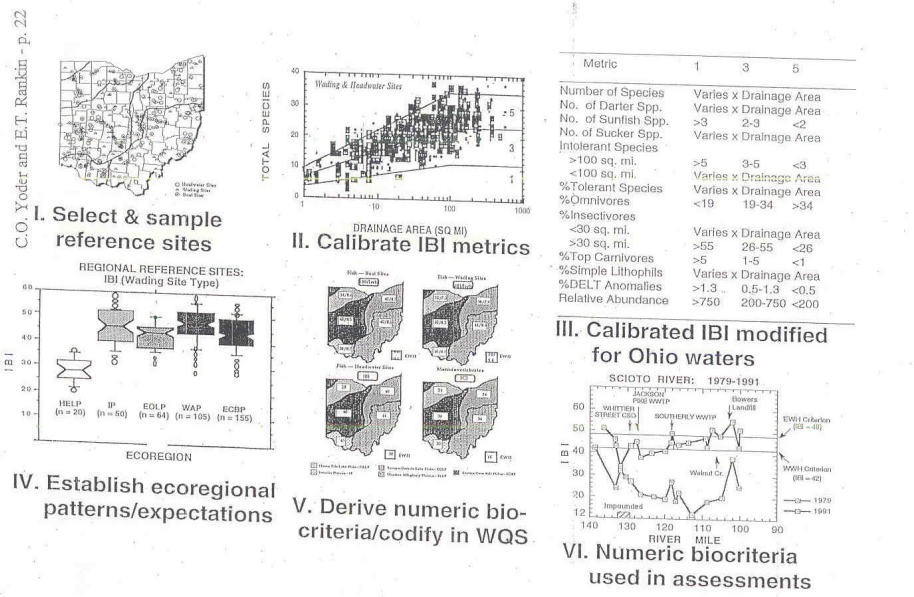
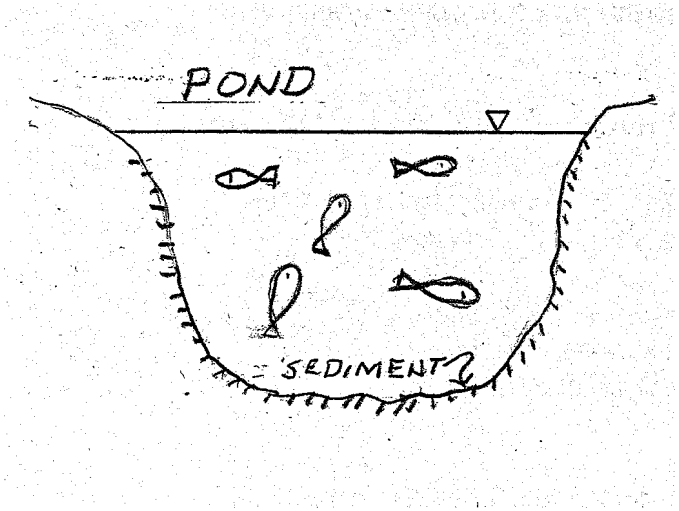


Figure 3. Six of the key steps in the derivation and use of numerical biological criteria for the Index of Biotic Integrity (wading site type). A similar process was used to derive numerical biocriteria for the Invertebrate Community Index (ICI; DeShon 1995).

ECOLOGICAL



- **To establish concentrations of contaminants in sediment**
  - **take 1 sample of sediment on pond bottom**
  - **take 7 samples of sediment on pond bottom**
  - **take 30 samples of sediment on pond bottom**
  - **take entire pond bottom**
- **Which number gives best representation of sediment concentration that the fish population would eat ?**

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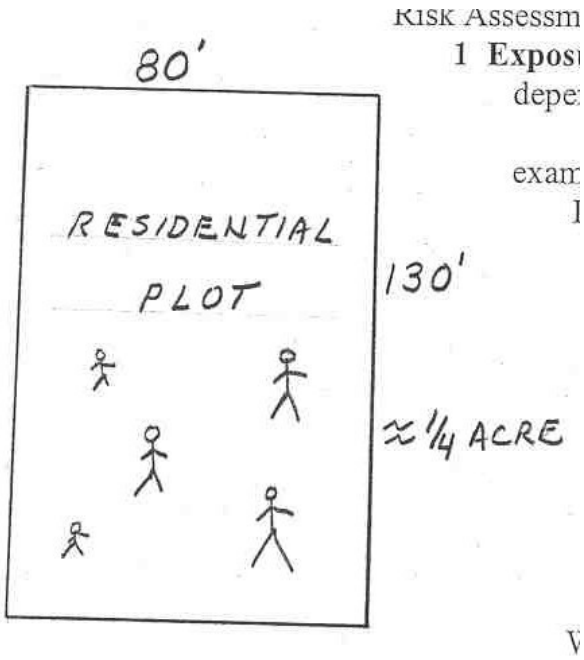
HUMAN HEALTH – RESIDENTIAL SCENARIO



Risk Assessment Process

1. **Exposure Assessment –** determines how much a person will intake, depends upon a great many exposure assumptions,
   - Exposure I_i = **C_s** x (constant, real, positive number)
   - **C_s = concentration of COPC in soil (mg/kg)**
2. **Toxicity Assessment –** determines concentrations of contaminants that cause adverse health effects in individuals
3. **Risk Characterization –** combines (**Exposure Assessment**) with (**Toxicity Assessment**) to quantitatively defines risk

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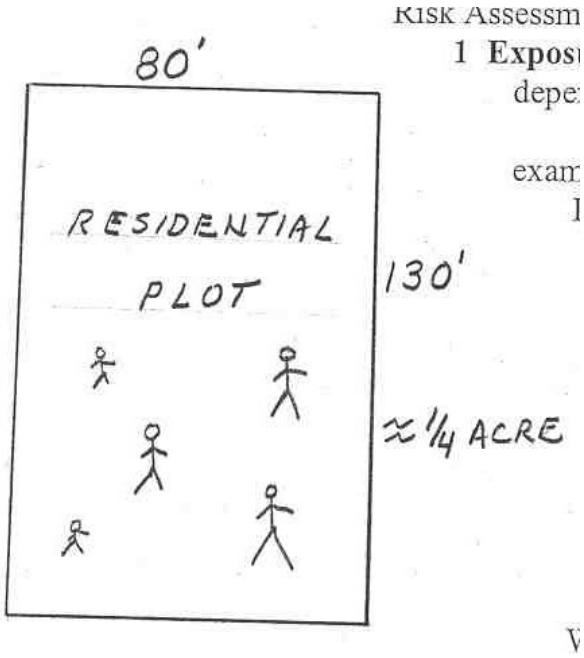
HUMAN HEALTH – RESIDENTIAL SCENARIO



- **BOTTOM LINE - <u>risks are directly proportional to Cs = measure of concentration of contaminant in soil</u>**
  - 1 sample would provide a very crude estimate of C_s
  - 7 samples would be a better estimate of C_s
  - 30 samples would be a much better estimate of the C_s
  - Best, truest measure would be to scrape up the entire 80’ x 130’ x 1’ deep volume and get the true average
- What we do now is C_s = 95 % UCL OF MEAN
  - Vast majority of time, have very few samples within an exposure area
  - Almost always, the data is not normally distributed, so revert to the maximum
  - Almost always, the data is not even log normally distributed, so revert

Rest of Discussion…

Rest of Discussion addresses How to Best Determine C_s = concentration of contaminant on surface soil

1. Best and one true measure of C_s would be to dig up entire 80’ x 130’ x 1’ deep volume and determine average of that mass,
2. Since cannot feasibly dig up the entire area, must “sample” to determine an estimate of C_s
3. Methodology for practically determining much more valid estimates of C_s are described in detail by Chuck Ramsey in

Sample – Measure / Decision Error

- Total measurement variance V_{Total} is give by the sum of the individual component variances:

- $V_{Total} = V_{Field\ Sampling} + V_{Field\ Sample\ Processing} + V_{Laboratory\ Sub\text{-}sampling} + V_{Analytical}$

Sample – Measure / Decision Error

- $V_{\text{Field Sampling}}$ – can be huge
  - Must be at right or appropriate location - mitigated by having main stakeholders in field at beginning of field sampling
  - Insufficient mass to adequately characterize effects of compositional heterogeneity
  - Not enough samples to account for distributional heterogeneity
    - 1 sample location
    - 7 sample locations
    - 30 sample locations

Sample – Measure / Decision Error

- $V_{\text{Field Sample Processing}}$ - how select what part of sample goes to the laboratory ?
- $V_{\text{Laboratory Sub-Sampling}}$ -
  - lab will take 1 or 2 grams from an 8 oz sample jar
    - how do they get a representative 1 or 2 gm from the 8 oz jar ?

Sample – Measure / Decision Error

BOTTOM LINE- <u>what we are doing now is say 1 or 2 gms from a discrete sample characterizes a somewhat large area</u>

- $V_{Analytical}$ - much effort is typically spent here
  - one of biggest problems when doing duplicate, split or replicate samples is getting similar samples from the field - huge problem
- Statistical Error - when do a few discrete samples, typically get huge range of values,non-detect, non-detect, 1000 mg/km, 800 mk/kg, 8,000 mg/kg
- Typically, do statistical calculations to determine Cs- something is wrong with the procedure when there is this much variation !!!

Basic Sampling Theory

- Basic Sampling Theory to determine a good approximation of the average
  - How much sample to collect
  - How to collect the sample
- Basic phenomenon that causes all sampling error is heterogeneity

Basic Sampling Theory

- Two types of heterogeneity
  - Compositional
    - difference in composition of particles that make up the population (peas - basketballs - smashed cars)
    - applies to the analyte of interest, say lead for instance

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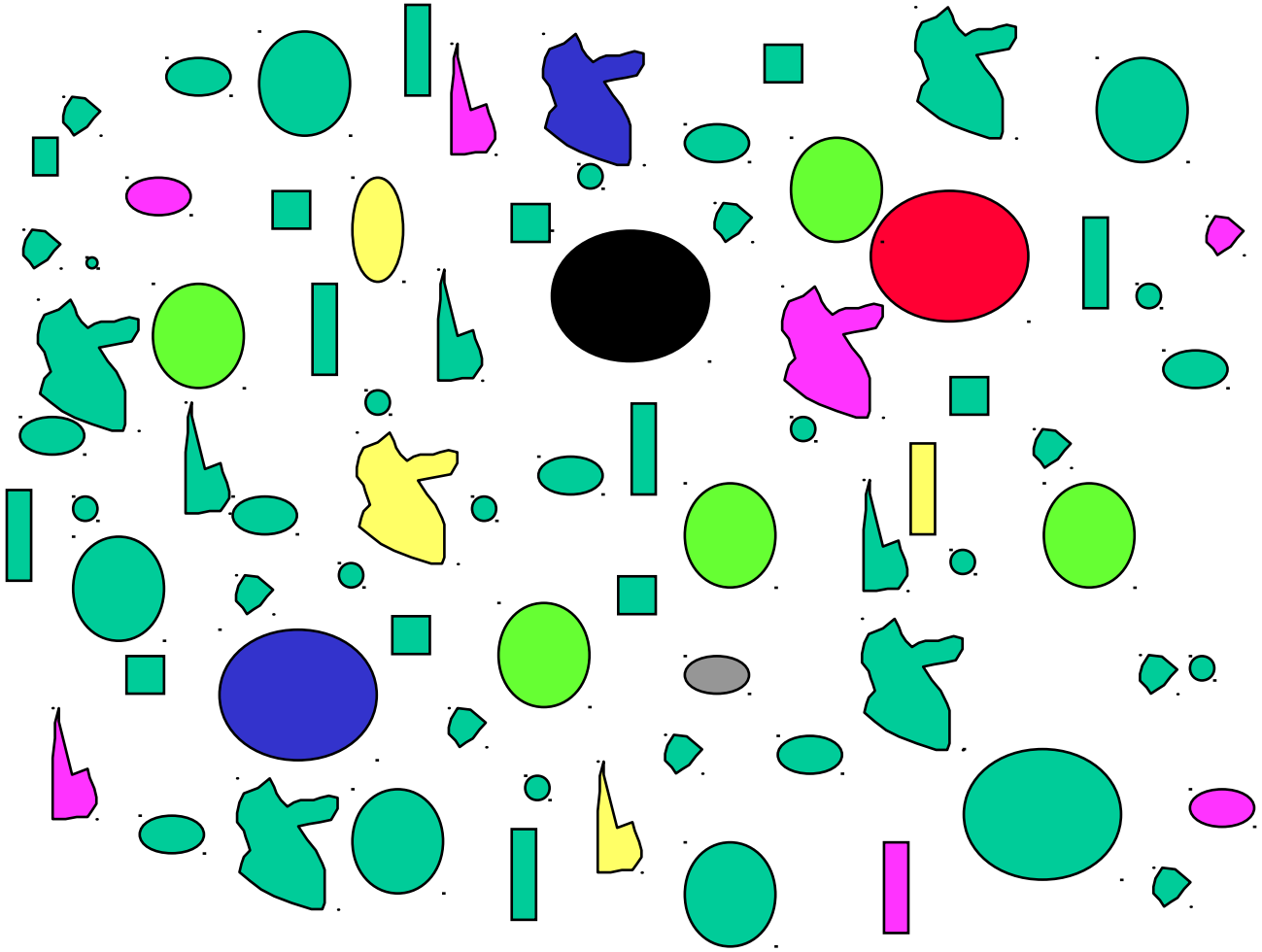

Basic Sampling Theory

- Two types of heterogeneity
  - Compositional
    - difference in composition of particles that make up the population (peas - basketballs - smashed cars)
    - applies to the analyte of interest, say lead for instance
  - Distributional
    - Non-random distribution of particles due to gravity, chemical attractions, human activity, air resistance, etc in time
    - Particles may be different
    - shape
    - size
    - contaminant concentration

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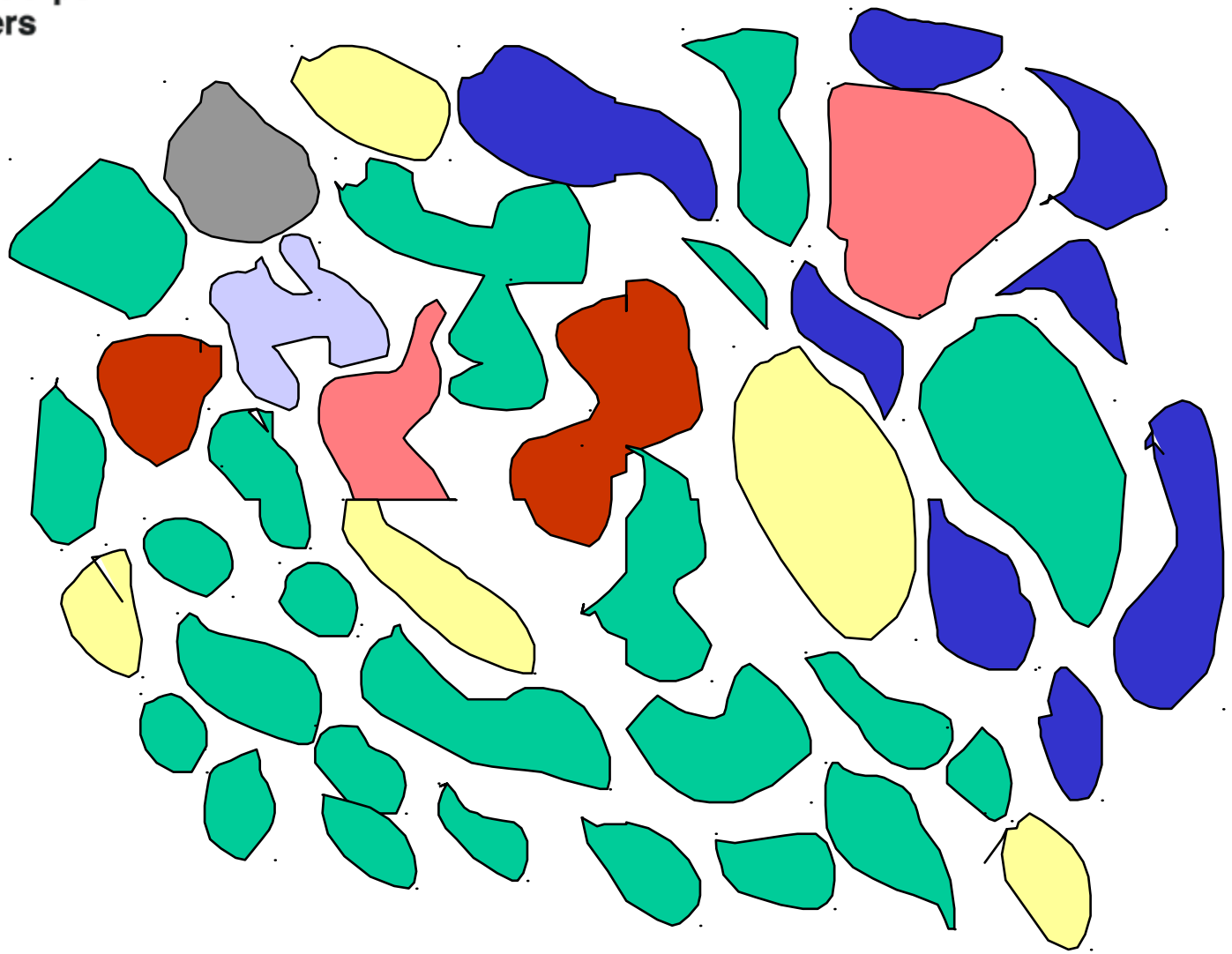
One Corps Serving the Army and the Nation



Basic Sampling Theory

- How is heterogeneity controlled ???????
  - Compositional Heterogeneity leads to fundamental error which is controlled by taking enough sample mass

Basic Sampling Theory

Fundamental Error

$$FE^2 = \frac{clfgd^3}{M_S} \quad ; \; M_L >> M_S$$

c - mineralogical factor (g/cm³)
l - liberation factor (no units)
f - shape factor (no units)
g - granulometric factor (no units)
d - maximum particle size <5% oversize (cm)
M_s - mass of the sample (g)
M_L - mass of the lot (g)

If the mass of the lot is greater than ten times the mass of the sample, this formula can be used. The error introduced by this approximation can be significant when the mass of the lot is close to ten times the mass of the sample, so be careful when you use the approximation.

The mass of the lot is usually much greater than the mass of the sample in the field. This may not be true for laboratory subsampling, however. In the case of splits, it is often not true and the previous formula should be used.

"clfg" is referred to as the sampling constant C.

"d" is the sieve size that retains no more than 5% of the mass of the lot. The proportion of the 5% must be equivalent to the rest of the lot. One can imagine a case where this 5% oversize would contain all the contamination. While this is highly unlikely, if it is suspected, an investigation into the 5% oversize would be warranted.

Basic Sampling Theory

- How is heterogeneity controlled ???????
  - Compositional Heterogeneity leads to fundamental error which is controlled by taking enough sample mass
    - $V_{(\text{Field Sample Size})} = (22.5 \times d95^3) / (\text{Sample Mass-gms})$

      if use d95 = 2 mm equals #10 seive size
    - Take enough sample mass to represent all particles, especially the larger ones, for the materials we work in a good minimum amount of sample mass is 30 gms
  - Distributional Heterogeneity is controlled by
    - taking an appropriate number of random increments

Current Environmental Sampling Procedures

- **Take limited number of discrete samples to characterize an exposure area**,
  - samples are not representative of an exposure area because so few of them
  - artificially increases variability, which reduces confidence, typically; ND, ND, 800, 1000, 25,000
  - generates outliers, which causes much stress (ignore them, resample, include ????)
  - results are no where near close to being normally distributed
  - results are no where near close to being log-normally distributed
  - samples are not reproducible
  - splits and replicates do not agree
  - sampling error is completely ignored
  - underestimates the mean or average, typically by several orders of magnitude
  - sampling results are not legally defensible

Proposed Sampling Procedure

- Proposed Sampling Procedure – discussion only applies to surface soil sampling and sediment
- Over an “exposure area”, or some other area whose delineation makes sense, but generally never smaller than ¼ to ½ acre,
  - Take 30 – 50 multi-increments in a stratified random manor,
    - number of multi-increments depends on heterogeneity
    - Stratified random provides locations over entire area of interest
  - Field prepare about 1000 gm of soil the is < 2 mm (#10 sieve) to send to the lab
    - dry and sieve on a #10 sieve the entire multi-increment sample
    - spread out on flat surface
    - take about 30, 1-gm increments from the flat surface and put in sample jar, or two jars if doing a split
    - send the jar(s) to the lab(s)
    - Insist that the laboratory use adequate subsampling procedures, not just take 1 or 2 gms off the top of the jar

Proposed Sampling Procedure

- Will generate more
  - Representative samples
  - Less variable samples
  - Legally defensible results
  - Valid approximation of the average soil concentration, Cs, for risk assessment

ONLY WAY WE SHOULD EVER PREPARE DUPLICATE OR SPLIT SAMPLES

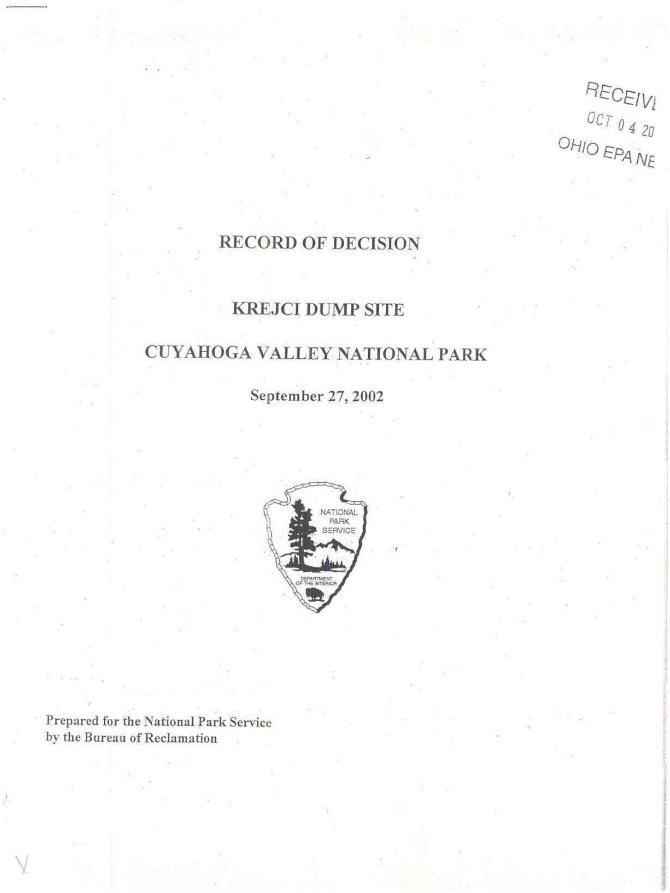
How Implement Proposed Sampling Procedures

- How Implement Proposed Sampling Procedures, especially in middle of our projects????
  1. Acknowledge limitations of current sampling procedures
  2. Project teams work out to their conditions,
  3. Applicable to almost all our sampling needs
     - Determination of site background - would provide legally defensible, representative values without the typical outliers
     - Remedial investigations - would provide representative samples over an appropriate exposure unit on which to base risk calculations and extent determinations
     - Closure sampling -would provide a representative sample across the exposure area that is legally defensible

Ravenna Team Buy-In

1. Ravenna Army Ammunition Plant Environmental Team met 28 – 30 Jan at a state park in Ohio
   - Team composed of Ohio EPA people (including risk assessors, geologists, biologists) contractors, OSC facility manager, AEC ROM, Corps people,
   - ALL were very supportive of the new way of sampling
2. OSC facility manager had asked Chuck previously if this methodology had been applied any place else, and approved

Already Been Done



RECEIVE
OCT 04 20
OHIO EPA NE

RECORD OF DECISION

KREJCI DUMP SITE

CUYAHOGA VALLEY NATIONAL PARK

September 27, 2002

Prepared for the National Park Service
by the Bureau of Reclamation

Doubts about Practicality

1. Ravenna Army Ammunition Plant Environmental Team met 28 – 30 Jan at a state park in Ohio
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2. OSC facility manager had asked Chuck previously if this methodology had been applied any place else, and approved by any regulators
3. State experience
4. In checking for sampling tools, etc

Again, already been done

AMS Soil Recovery Probes and Liners
3121

Top quality probes are made of high grade alloy tubing with chrome plating or durable stainless steel. Unslotted models require removable liners. Slotted models can be used with or without liners. Cross handle, plastic liner, and two end caps included with each probe. May be used with AMS extensions and hammer attachment. Liners for all AMS soil recovery probes are 1-3/4" longer than the size indicated to accomodate the AMS "reach and grab" liner removal system.

7/8" Diameter Probes

77486	7/8" x 12" Unslotted Alloy Probe	2 lbs.	$136.00
77424	7/8" x 12" Unslotted Stainless Steel Probe	2.25 lbs.	$193.00
77493	7/8" x 12" Slotted Alloy Probe 10" Slot	2 lbs.	$163.00
77488	7/8" x 24" Unslotted Alloy Probe	2.5 lbs.	$150.00
77425	7/8" x 24" Unslotted Stainless Steel Probe	2.5 lbs.	$204.00
77494	7/8" x 24" Slotted Alloy Probe 13" Slot	2.5 lbs.	$176.00

Liners & Liner Caps

For all 7/8" probes

77498	3/4" x 12" Butyrate Plastic Liner	2 oz.	$1.25
77525	3/4" x 12" Stainless Steel Liner	6 oz.	$7.70
77522	3/4" x 24" Butyrate Plastic Liner	2 oz.	$1.85
77527	3/4" x 24" Stainless Steel Liner	10 oz.	$10.45
77523	3/4" Polyethylene Liner Caps, Case of 100	6 oz.	$7.00
77554	Stainless Steel Cap Insert, Requires 3/4" Polyethylene Liner Caps	1 oz.	$2.35
77869	7/8" Stainless Steel Plunger for Removing Cores	1 lb.	$41.50

1-1/8" Diameter Probes

77490	1-1/8" x 12" Unslotted Alloy Probe	2.25 lbs.	$150.00
77651	1-1/8" x 12" Unslotted Stainless Steel Probe	3 lbs.	$204.00
77495	1-1/8" x 12" Slotted Alloy Probe 10" Slot	2.25 lbs.	$176.00
77492	1-1/8" x 24" Unslotted Alloy Probe	3 lbs.	$161.00
77652	1-1/8" x 24" Unslotted Stainless Steel Probe	4.5 lbs.	$219.00
77496	1-1/8" x 24" Slotted Alloy Probe 13" Slot	2.5 lbs.	$187.00

Liner & Liner Caps

For all 1-1/8" Probes

77529	1" x 12" Butyrate Plastic Liner	2 oz.	$1.95
77533	1" x 12" Stainless Steel Liner	8 oz.	$8.30
77531	1" x 24" Butyrate Plastic Liner	3 oz.	$2.50
77535	1" x 24" Stainless Steel Liner	13 oz.	$11.70
77536	1" Polyethylene Liner Caps, case of 100	9 oz.	$7.00
77555	Stainless Steel Cap Insert, Requires 1" Polyethylene Liner Caps	1 oz.	$2.10
77870	1-1/8" Stainless Steel Plunger for Removing Cores	2.25 lbs.	$41.50

AMS Soil Probes
3119

Three styles to choose from – regular chrome molybdenum steel, chrome-plated chrome molybdenum steel, or stainless steel. Chrome-plated chrome molybdenum probes are more rust-resistant than regular probes. Stainless steel probes are the most durable, rust-resistant, and are easily decontaminated. All probes have 7/8" outside diameter and heat-treated, wear-resistant bit. Swedged on the bit end and bored to 11/16" diameter – providing ideal clearance for easy sample removal. Nine inch cross handle threads onto each probe. 21" Soil probes retrieve 10"L core sample; 33" soil probes retrieve 13"L core sample. May be used with AMS extensions or hammer attachment.

77450	21" Regular Soil Probe	1.5 lbs.	$41.50
77451	21" Chrome-plated Soil Probe	1.5 lbs.	$53.50
77653	21" Stainless Steel Soil Probe	1.75 lbs.	$99.00
77452	33" Regular Soil Probe	2 lbs.	$53.50
77453	33" Chrome-plated Soil Probe	2 lbs.	$59.00
77654	33" Stainless Steel Soil Probe	2 lbs.	$109.00

Soil Probe Accessories

77454	Hammer Attachment, Thread-On	10.25 lbs.	$134.00
77421	Optional Soil Ejector for 33" Soil Probes	6 oz.	$27.00
77581	Optional Soil Ejector for 21" Soil Probes	4 oz.	$26.00

AMS Open-End Soil Probe
3120

This 1-1/8" x 33" probe is designed like slotted probes but is open to the tip for faster removal of soil samples. Chrome-plated for durability and rust-resistance. Cross handle included.

77881	AMS Open-End Soil Probe	2.75 lbs.	$106.00

AMS One-Piece Step Probe
7009

Just step down on the fixed step of this one-piece probe to apply pressure and obtain a soil sample. Sample can then be easily removed. Made of aircraft-quality alloy steel and coated with chrome plating, the probe has a 13" long x 7/8" diameter slot for the sample. Total probe length: 40".

77636	AMS One-Piece Step Probe	2 lbs.	$56.50

Environmental Science

Slotted Soil Recovery Probe

Unslotted Soil Recovery Probe

Made in USA United States

Soil Probe

Open-End Soil Probe

$59.00

One-Piece Step Probe

Made in USA United States

Plunger 77869

Again, already been done

THE OHIO STATE UNIVERSITY EXTENSION AGRONOMY FACTS

Ohio State University Extension
Department of Horticulture and Crop Science
2021 Coffey Road, Columbus, Ohio 43210-1044

Soil Sampling, Handling and Testing

AGF-206-95

The accuracy of a fertilizer recommendation depends on how well the soil sample on which the recommendation was based represents the area on which the recommendation will be used. The physical and chemical characteristics of soil in an area can vary considerably from place to place because of natural factors and the management to which the area has been subjected. Natural variation arises from soil-forming processes (such as mineral weathering and erosion) that lead to accumulations or losses of nutrients at different sites. Management factors might include tillage and fertilization practices, crop selection and irrigation. It may be necessary to take many samples from a given area (at random or in a systematic manner) to assess its fertility accurately.

Sampling Strategies

Four variables are generally considered when taking soil samples:

1. The spatial distribution of samples across the landscape.
2. The depth of sampling.
3. The time of year when samples are taken.
4. How often an area is sampled.

Proper consideration of these variables ensures that the sample accurately reflects the fertility of the area in question and allows for the best possible fertilizer recommendations.

Sample Distribution

Sample distribution usually depends on the degree of variability in a given area. In relatively uniform areas smaller than 25 acres, a composite sample of 20 to 30 cores taken in a random or zigzag manner is usually sufficient. Larger areas are usually subdivided into smaller ones. Non-uniform areas should be subdivided on the basis of obvious differences such as slope position or soil type.

Ravenna FW SW Study

Ravenna Facility-Wide Surface Water Sampling Locations

Creek Locations

- Hinckley Creek Basin- 4 locations (upstream to downstream)
- Sand Creek Basin- 11 locations (upstream to downstream)
- South Fork Eagle Creek- 5 locations (upstream to downstream)
- No Name Creek Basin- 4 locations (upstream to downstream)

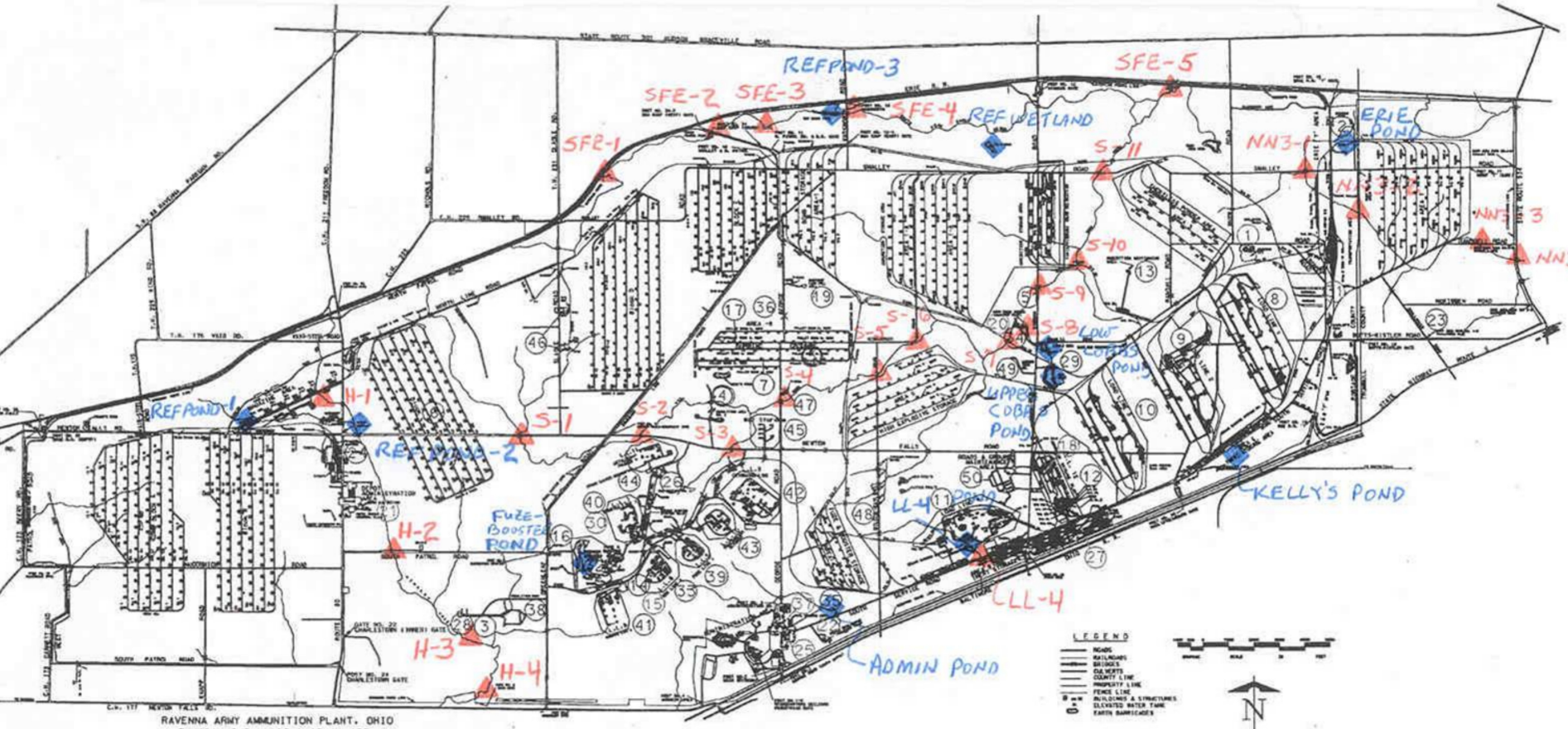
Pond Locations

- Reference Ponds- 3 ponds

RVAAP FACILITY-WIDE SEDIMENT/SURFACE WATER SAMPLING LOCATIONS

▲ = STREAM SAMPLING LOCATION

◆ = POND SAMPLING LOCATION



RAVENNA ARMY AMMUNITION PLANT, OHIO
ENVIRONMENTAL AREAS OF CONCERN

UARRY LANDFILL
NG GROUNDS
AREA #1
AREA #2
BURNING GROUNDS
ARRY
HAZ WASTE STORAGE
1
2
3
4
12
200
6. EVAPORATION UNIT
6
STER BURN PITS/LANDFILL
ON FURNACE
12 PINK WATER TRT PLANT
ORTH OF WINKLEPECK BG

20. SAND CREEK SEWAGE TRT PLANT
21. DEPOT SEWAGE TRT PLANT
22. GEORGE ROAD SEWAGE TRT PLANT
23. UNIT TRANING SITE- WASTE OIL TANK
24. RESERVE UNIT MAINT AREA WASTE OIL TANK
25. BLDG 1034 MOTOR POOL WASTE OIL TANK
26. FUZE & BOOSTER AREA SETTLING TANKS
27. BLDG 854 - PCB STORAGE
28. MUSTARD AGENT BURIAL SITE
29. UPPER & LOWER COBBS POND COMPLEX
30. LOAD LINE 7 PINK WATER TREATEMENT PLANT
31. DRE PILE RETENTION POND
32. 40 & 60 MM FIRING RANGE
33. FIRESTONE TEST FACILITY
34. SAND CREEK DISPOSAL ROAD LANDFILL
35. BLDG 1037 - LAUNDRY WASTEWATER SUMP
36. PISTOL RANGE
37. BLDG T - 4452 PESTICIDE STORAGE
38. NACA TEST AREA

39. LOAD LINE 5 / FUZE LINE 1
40. LOAD LINE 7 / BOOSTER LINE 1
41. LOAD LINE 8 / BOOSTER LINE 2
42. LOAD LINE 9 / DETONATOR LINE
43. LOAD LINE 10 / PERCUSSION ELEMENT
44. LOAD LINE 11 / ARTILLERY PRIMER
45. WET STORAGE AREA
46. BLDG'S F-15 AND F-16
47. BLDG T-5301 DECONTAMINATION
48. ANCHOR TEST AREA
49. CENTRAL BURN PITS
50. ATLAS SCRAP YARD
51. DUMP ALONG PARIS-WINDHAM ROAD

○ = CERCLA

○ = RCRA

○ = OTHER REGULATORY

RAVENNA ARMY AMMUNITION PLANT
RAVENNA, OHIO
OPERATED BY RAVENNA ARSENAL, INC.

APPROVED	SIGNATURE	DATE	TITLE
SAFETY			GENERAL AREA MAP
TECHNICAL MANAGER			
PRODUCTION			
ENGINEERING			
GENERAL MANAGER			

Ravenna FW SW- Fish Shocking in Creek

Ravenna FW SW- Fish Sampling Creek Equipment

Ravenna FW SW- Fish Caught in Creeks

US Army Corps of Engineers

Ravenna FW SW- Sediment Sampling in Creek

Ravenna FW SW- Fish Shocking in Ponds

Ravenna FW SW- Shocked Fish in Ponds

Ravenna FW SW- Sediment Collection in Ponds

Ravenna FW SW- Sieving Out +10 Creek Sediment

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Ravenna FW SW- Processing Field Sample

Ravenna FW SW- Placing Processed Sediment in Jars

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Ravenna FW SW- Sand Creek Analytical Results

	Sand Creek Site ID/ Location/Sample Number													
	S-1, Sand Creek West of Slagle Rd		S-2, Sand Creek Trib. At Newton Falls Rd		S-3, Sand Creek Trib 2 at Newton Falls Rd		S-4, Sand Creek at George Rd		S-5, Sand Creek at Wilcox-Wayland		S-5, Sand Creek at Wilcox-Wayland		S-5, Sand Creek at Wilcox-Wayland	
	FSW-SD-005-0000	FSW-SW-005-0000	FSW-SD-006-0000	FSW-SW-006-0000	FSW-SD-007-0000	FSW-SW-007-0000	FSW-SD-008-0000	FSW-SW-008-0000	FSW-SD-009-0000	FSW-SW-009-0000	FSW-SD-039-0000	FSW-SW-039-0000	FSW-SD-009-0000-QA	FSW-009-SW-0000-QA
	Sediment	Surface Water	Sediment	Surface Water	Sediment	Surface Water	Sediment	Surface Water	Sediment	Surface Water	Sediment	Surface Water	Sediment	Surface Water
Analyte	mg/kg	ug/L	mg/kg	ug/L	mg/kg	ug/L	mg/kg	ug/L	mg/kg	ug/L	mg/kg	ug/L	mg/kg	ug/L
Aluminum	2350	111	1810	138	5280	105	1880	113	1790	69.5	1810	83.3	1550	
Antimony	0.29		0.2				0.22			2.2	0.27			
Arsenic	7.1		5.3		6.2		5.6		5.5		4.8		4.8	
Barium	15.8	20.3	10.7	20.5	56.3	23.7	15.5	21.2	13.3	25.9	12.6	25.8	11.1	25.1
Berylium	0.14		0.11		0.52		0.19		0.18		0.15			
Cadmium														
Calcium	633	36600	1630	35700	5440	33100	612	33900	1090	41800	625	41900	597	42700
Chromium	3.7		3	1.1	8	1	3.5		3.7	0.92	3.3	0.64	3	
Cobalt	3.3		2.4		6.7		3		2.6		2.5			
Copper	5.2		5.1	1	10.3	1.1	6.2	2.1	5.2	3.4	4.4	1.6	5.4	
Iron	9060	479	7580	610	18400	566	9530	566	9440	500	8150	563	6770	
Lead	5.1	3.1	4.7	2.4	13.5		5.5		4.7	2.3	4.4	2.4	4.2	
Magnesium	873	8880	1000	8750	1940	9620	596	8440	779	10900	643	11000	518	10700
Manganese	253	51.9	190	49.2	1160	233	280	25.6	232	54.9	196	54	169	
Nickel	6.3		4.8		12		6.2		5.4		4.8		4.4	
Potassium	283	1920	308	1680	671	1140	281	1400	251	1580	288	1510		
Selenium		2.1			0.23			4.2						
Silver														
Sodium	57.5	11300	66.6	8210	94	5960	45.2	5910	57.3	6690	63	6620		5820
Thallium					0.45									
Vanadium	4.9		3.7	0.69	9.5		4.3		4.4	0.63	4.2		3.5	
Zinc	27	8.1	70.4	5.1	44.9	5.8	26.1	6.3	29.8	4.5	24	4.9	21.9	

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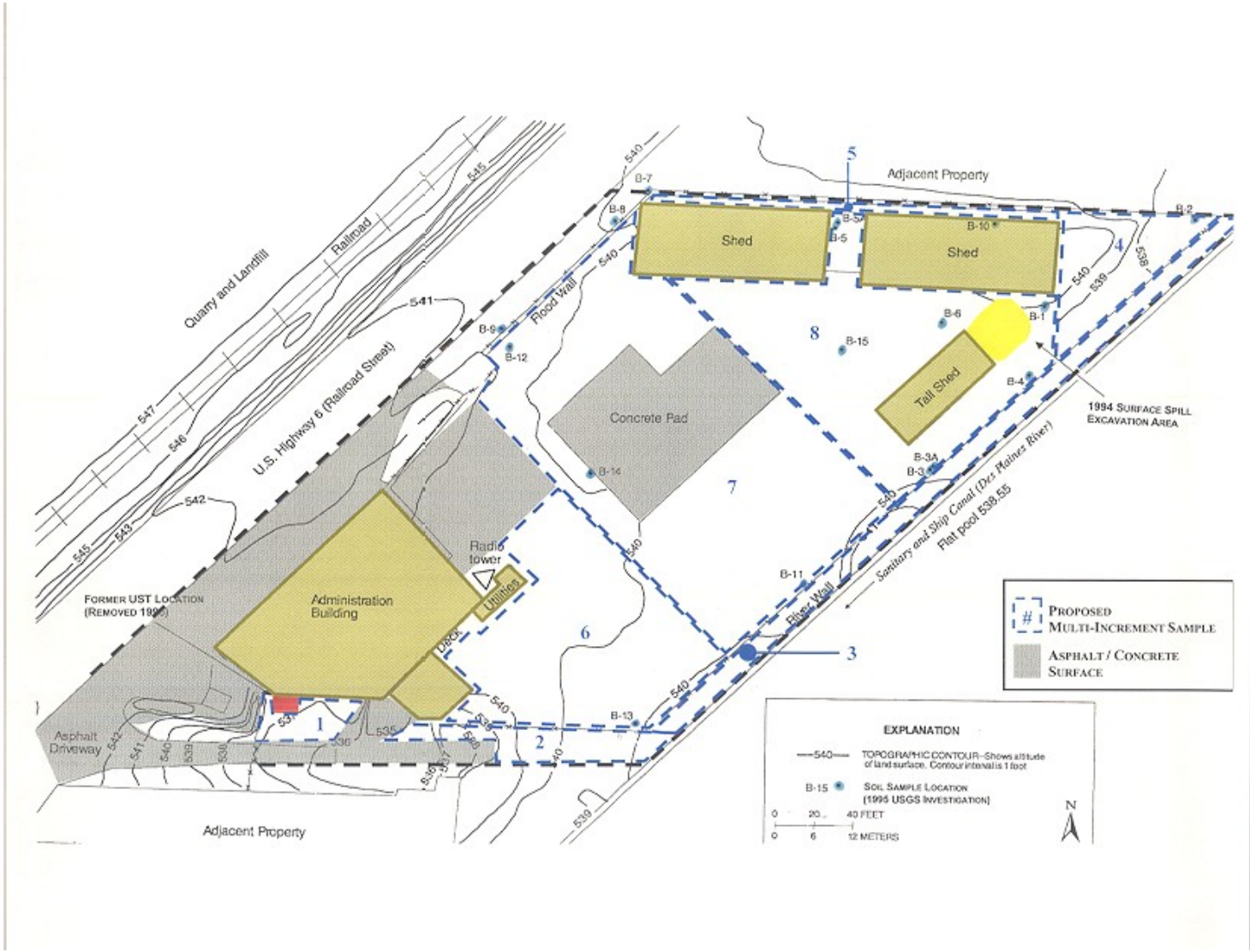
Ravenna FW SW- Pond Sediment Analytical Results

	Study Ponds Site ID/ Location/Sample Number													
	Fuze/Boost Pond		**Unnercobb Pond**		**Lowcobb Pond**		**LL4Pond**		**LL4Pond - Duplicate**		**LL4Pond - OA Split**		**Admiropond**	
	FSW-SD-0029-0000	FSW-SW-029-0000	FSW-SD-0030-0000	FSW-SW-030-0000	FSW-SD-0031-0000	FSW-SW-031-0000	FSW-SD-032-0000	FSW-SW-032-0000	FSW-SD-040-0000	FSW-SW-040-0000	FSW-SD-032-0000	FSW-SW-032-0000	FSW-SD-033-0000	FSW-SW-033-0000
	Sediment	Surface Water	Sediment	Surface Water	Sediment	Surface Water	Sediment	Surface Water	Sediment	Surface Water	Sediment	Surface Water	Sediment	Surface Water
Analyte	mg/kg	ug/L	mg/kg	ug/L	mg/kg	ug/L	mg/kg	ug/L	mg/kg	ug/L	mg/kg	ug/L	mg/kg	ug/L
Aluminum	9760	148	9030	119	15400	226	11400	170	13900	154	11400		15600	247
Antimony	3.5	4.8	1		1.3	3.4	0.98						0.53	
Arsenic	7.9		6.5		10.2		9.5		12.6		10.6		11.1	
Barium	96.7	55.4	78.9	16.2	116	13.5	96.9	21.1	113	20.5	101	19.8	85.1	44.4
Berylium	0.55		0.48		0.83		0.62		0.75				0.7	
Cadmium	1.3		0.6		1.2		0.62		0.74				0.085	
Calcium	2150	11400	1960	24300	2550	20100	4040	21300	5320	21400	4010	21800	1560	35200
Chromium	20.1	0.99	18.6	1	121	1.1	15.3	0.92	18.9	0.67	14.8		20	1.1
Cobalt	8		7.7		12		9.8		11.2		10.7		9.9	1.2
Copper	57.9	2.5	23	5.1	120	2.9	19.2	3	23.5	3.6	19.3		20.2	
Iron	22300	294	16200	1300	26000	1350	23700	1410	28000	1420	25600	1310	25500	1580
Lead	177	5.8	17.8	3.3	34.2		18		24	2.5	18.9		32.3	2.3
Magnesium	2290	2920	1530	3600	2600	3300	2810	4900	3390	4930	2890	4760	3050	10000
Manganese	263	32.2	383	188	602	190	409	153	448	139	489	141	357	865
Nickel	20.5		14.4		24.6		20.5		23.9		22.8		21	
Potassium	1170	1160	858	1570	1640	1580	1500	1420	1880	1400			1450	2600
Selenium		2	1.1		1.6		1.5		1.6				1.3	2.6
Silver	0.19		1.1		1.5									
Sodium	82.9	1720	106	2070	203	2040	114	2420	161	2430		1260	152	6180
Thallium													0.85	
Vanadium	18.7		15.6		24.5	0.82	19.1	0.92	23.3	1	18.8		29	0.68
Zinc	632	33.8	153	8	259	4.2	172	3.7	196	5.7	185		77.4	6.1

Joliet Former Army Reserve Site



Joliet Former Army Reserve Site- East Side

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Joliet Former Army Reserve Site- Central View

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Joliet Former Army Reserve Site- Sample Area 1

Wooden Stakes at 30 Random Sub-Sample Locs

Joliet Former Army Reserve Site – Sampling Area #1

Asphalt Pave. Present Over Portions of Area #1

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Joliet Former Army Reserve Site- Sample Area #2

Orange Flags at Individual Sub-Sample Locations

Joliet Former Army Reserve Site- One of 30 Incremental Shallow Soil Locations with Area #3

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Joliet Former Army Reserve Site- Sample Area #4

Note Orange Flags at Individual Increment Locations

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Joliet Former Army Reserve Site- Shallow Soil Sampling at Individual Location with Area #4

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Joliet Former Army Reserve Site-Portions of Sample Area #8- Note Gravel Surface

Joliet Former Army Reserve Site- Shallow Soil Sampling within Sample Area #8

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Joliet Former Army Reserve Site- Composite of 30 Sub-
Samples From Area #1 Pushed Through #4 Sieve

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Joliet Former Army Reserve Site- Typical Materials From Sample Area #1 Retained on #4 Sieve

Joliet Former Army Reserve Site- Materials from Sample Areas #1 & #2, Passed #4 Sieve, Air Drying

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Joliet Former Army Reserve Site- Materials from Sample Areas 5,6,7,8; Passed #4 Sieve, Air Drying

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Joliet Former Army Reserve Site - Processing Material

Ground within Brass Pan- Minus #10 Sieve in Center-

Minus #4 Sieve at

Joliet Former Army Reserve Site- Sample Processing Room

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Joliet Army Reserve Analytical Results

JOLIET U.S. ARMY RESERVE CENTER (IL052)
Grnd = ground sample…. samples were air dried (samples 1, 2 and 3 dried overnight; while sample 4 through 8 dried within 4 hours), passed through #4 and #10 ground and then passed again through #10 sieve. . Grinding approximated 5 to 10 seconds. Samples not ground were passed through # 4 sieve and then through # 10 sieve.

Name	TACO TIER I Criteria mg/kg	Area 1 <#4 Un-ground	Area 1 <#10 Un-ground	Area 1 <#10 QA Un-ground	Area 1 <#10 Ground	Area 2 <#4 Un-Ground	Area 2 <#10 Un-Ground	Area 2 <#10 Ground	Area 3 <#4 Un-Ground	Area 3 <#10 Un-Ground	Area 3 <#10 Ground	Area 4 <#10 Un-Ground	Area 4 <#10 Ground	Area 5 <#10 Un-Ground	Area 5 <#10 Ground	Area 6 <#10 Un-Ground	Area 6 <#10 Ground	Area 7 <#10 Un-Ground	Area 7 <#10 Ground	Area 8	Area 8 grnd
Naphthalene	1.8	0.47 U	0.47 U	0.59 U	0.46 U	0.44 U	0.44 U	0.43 U	0.19 J	0.15 J	0.19 J	2.2 U	2.2 U	0.21 U	0.042 U	0.2 U	0.21 U	0.076 J	0.41 U	0.41 U	0.2 U
Acenaphthylene		0.49 U	0.49 U	1.12 U	0.47 U	0.45 U	0.45 U	0.44 U	1.4	0.46 U	0.44 U	2.3 U	2.2 U	0.11 J	0.043 U	0.21 U	0.21 U	0.21 U	0.42 U	0.42 U	0.21 U
Acenaphthene	120,000	1.0 U	1.0 U	0.66	0.98 U	0.94 U	0.94 U	0.92 U	0.95 U	0.96 U	0.92 J	4.7 U	4.7 U	0.46 U	0.09 U	0.44 U	0.44 U	0.44 U	0.88 U	0.88 U	0.44 U
Fluorene	82,000	0.016 J	0.026 J	0.054 J	0.035 J	0.016 J	0.03 J	0.017 J	0.024 J	0.053 J	0.039 J	0.14 J	0.088 J	0.006 J	0.005 J	0.021 J	0.027 J	0.013 J	0.041 J	0.08 U	0.04 U
Phenanthrene		0.45	0.49	0.92	0.98	0.38	0.59	0.4	0.99	0.94	0.63	2.3	1.5	0.11	0.084	0.48	0.49	0.34	0.33	0.22	0.14
Anthracene	610,000	0	0.056	0.18 U	0.093	0.05	0.088	0.05	0.15	0.16	0.14	0.58	0.35	0.023	0.018	0.068	0.072	0.048	0.056	0.04	0.022
Fluoranthene	82,000	1	0.89	1.03	1.6	1	1.5	1.1	2.1	2	1.8	6	4.7	0.39	0.23	1	1.1	0.98	1	0.77	0.5
Pyrene	61,000	1	0.81	1.03	1.5	1	1.3	0.99	2.5	1.9	1.5	5.9	4.7	0.36	0.21	1.1	1.2	0.95	0.92	0.65	0.44
Benzo(a)anthracene	8	0.36	0.32	0.37	0.57	0.44	0.63	0.43	1.3	0.88	0.82	3.2	2.7	0.19	0.098	0.49	0.52	0.38	0.38	0.33	0.19
Chrysene	780	0.43	0.37	0.64	0.71	0.5	0.7	0.54	1.6	0.98	0.94	3.6	3.1	0.23	0.11	0.57	0.58	0.47	0.44	0.37	0.25
Benzo(b)fluoranthene	8	0.47	0.42	0.18	0.72	0.63	0.83	0.7	1.3	1	0.89	3.4	3.2	0.24	0.13	0.6	0.59	0.52	0.48	0.41	0.3
Benzo(k)fluoranthene	78	0.24	0.21	0.17	0.35	0.29	0.38	0.33	0.59	0.5	0.45	1.7	1.7	0.12	0.068	0.29	0.28	0.24	0.24	0.2	0.14
Benzo(a)pyrene	0.8	0.59	0.5	0.38	0.76	0.76	**0.94**	0.79	1.9	**1.4**	**1.1**	**4.3**	**4**	0.26	0.15	0.67	0.64	0.54	0.56	0.46	0.3
Dibenzo(a,h)anthracene	0.8	0.59	0.31	0.058	0.77	0.56	0.66	0.53	1.6	**1.4**	0.73	**2.7**	**2.5**	0.14	0.17	0.49	0.44	0.47	0.41	0.44	0.39
Benzo(ghi)perylene		0.51	0.33	0.36	0.78	0.62	0.75	0.61	1.4	1.1	0.85	3	2.9	0.16	0.11	0.48	0.52	0.43	0.37	0.31	0.22
Indeno(1,2,3-cd)pyrene	8	0.43	0.36	0.25	0.6	0.65	0.75	0.66	1.4	1.2	0.89	3.2	3.1	0.2	0.12	0.5	0.49	0.47	0.46	0.38	0.27

Analytical was screened against the TIER I TACO criteria and failures are read in bold. Failure was specific in areas 2, 3 and 4 for benzo(a)pyrene and benzo(a,h)anthracene. Area 4 was darker than any part of Areas 2 and 3. In the earlier study it was recorded by USGS that hits of benzo(a)pyrene had exceeded respective criteria.

There was not a consistent pattern where grinding could be implicated in affecting loss of the PNAs. For example naphthalene, the more volatile of the PNAs had consistent measurements between ground and unground except for Areas 5, 7 & 8. For the most part except for Areas 5, 7 & 8 there was little difference between ground and unground detects of PNAs

Conclusions

1. In contrast to the current discrete sample approach, multi-incremental is a viable method of collecting environment samples that are:
   - much more representative
   - repeatable
   - legally defensible
   - significantly less variable
     - thus providing greater confidence and less dependence on statistical manipulations.
2. Improved field sample processing provides for:
   - significantly improved representativeness of the portion of the total field sample that goes to the lab
   - vastly improved similarity of split samples, thus facilitating valid comparisons of laboratory quality control comparisons.
3. Improved laboratory sub-sampling provides for:
   - significantly improved representativeness of the portion of the jar sample that is analyzed
   - repeatable analytical results